ELEVATOR TRAFFIC CONTROL

Field of the Invention

This invention generally relates to controlling elevator traffic flow. More
5   particularly, this invention relates to grouping floors into sectors and assigning
particular cars to each sector.

Description of the Related Art

Elevator systems often include a plurality of elevator cars that each are
10   capable of serving many floors or all of the floors within a building. In many
instances, there are certain times during the day when the flow or volume of traffic on
the elevator system is greatly increased compared to others. Various techniques have
been developed to maximize the performance of the elevator system to improve the
handling capacity so that elevator passengers receive prompt service.

15   One such technique is shown in United States Patent No. 5,183,981, where
groups of floors within the building are grouped into contiguous sectors and particular
elevator cars are assigned to each sector. The sectoring concept has been shown to
provide significant improvement in handling capacity. In some instances the
improvement is on the order of fifty percent. Other techniques have been developed

20   to reduce the number of stops of an elevator car to improve handling capacity.

Those skilled in the art are always striving to make improvements. This
invention provides various approaches for grouping floors into sectors to enhance the
handling capacity of an elevator system.

25   ## SUMMARY OF THE INVENTION

In general terms, this invention is an elevator system handling capacity
enhancement. This invention includes grouping floors into sectors that include at
least one sector having at least one floor that is not contiguous with at least one other
floor in that sector.

30   A system designed according to this invention includes a plurality of elevator
cars, each capable of servicing a plurality of floors. A controller groups the floors

into sectors with at least one sector having at least one floor not contiguous with at least one other floor in that sector. At least one of the cars is assigned to each one of the sectors.

The techniques of this invention minimize the average number of stops and

5   significantly reduce the average reversal floor of an elevator car, which greatly enhances the handling capacity of the system

The various features and advantages of this invention will become apparent to those skilled in the art from the following detailed description of the currently preferred embodiment. The drawings that accompany the detailed description can be

10   briefly described as follows.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 schematically illustrates an elevator system incorporating a sector arrangement designed according to an example embodiment of this invention.

15   Figure 2 schematically illustrates an elevator system incorporating a sector arrangement designed according to another example embodiment of this invention.

Figure 3 schematically illustrates an elevator system incorporating a sector arrangement designed according to another example embodiment of this invention.

Figure 4 schematically illustrates an elevator system incorporating a sector

20   arrangement designed according to another example embodiment of this invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 schematically illustrates an elevator system 20 where a plurality of elevator cars 22, 24, 26, 28 and 30 are capable of servicing a plurality of floors within

25   a building. In the illustrated example, the elevator cars are shown at a lobby level L. The floors that are serviced by the cars are labeled 2-17 in the drawing. The floor numbers are for illustration purposes and do not necessarily correspond to actual building level numbers. Moreover, this invention is not limited to any particular number of elevator cars or floors within a building. Those skilled in the art who have

30   the benefit of this description will realize that the example illustration is one of many arrangements that can incorporate the techniques of this invention.

Each elevator car is moved through a hoistway by a machine (not illustrated) that is controlled by a controller. In the illustrated example the elevator car 22 is controlled by a controller 32. Similarly, the cars 24, 26, 28 and 30 have controllers 34, 36, 38 and 40, respectively, associated with them. The individual car controllers operate in a known manner to cause desired movement of the cars within the building to service landings responsive to requests made by passengers using hall call buttons or buttons on a car operating panel, for example.

The illustrated system also includes a main controller 42 that communicates with each of the individual car controllers 32-40. The main controller 42 determines information regarding traffic flow patterns for selectively assigning individual ones of the cars 22-30 to particular groupings or sectors of floors within the building to achieve enhanced system capacity. There are various known techniques for monitoring elevator system traffic flow within a building and for deciding how many floors to include in a sector and how to assign cars to a particular grouping of floors. Any of those known techniques can be used by the controller 42 to achieve that portion of the elevator system operation.

This invention provides a unique way of grouping the floors within the building into sectors so that at least one of the cars 22-30 can be assigned to a specific sector, which enhances the handling capacity of the elevator system, especially during more busy times of the day.

It is known, as described in various patents owned by the assignee of this invention, to group floors into a strictly contiguous arrangement where contiguous sectors each contain floors that are all contiguous with another floor in the sector and the sectors are all contiguous with each other. Such an arrangement is referred to in this description as strictly contiguous. This invention includes several grouping techniques that do not result in a strictly contiguous arrangement, but provides a nearly contiguous arrangement. As will become apparent below, some example implementations of this invention include some sectors that contain all contiguous floors, some sectors that are contiguous with other sectors, or a combination of the two, but none of them have a strictly contiguous arrangement.

Figure 1 illustrates one example sectoring arrangement designed according to this invention. In this example, each sector includes four floors within the building.

3

The car 24 is assigned to a first sector S_1, which in this example includes floors 14, 15, 16 and 17. The car 26 is assigned to a second sector S_2, which includes the floors 10, 11, 12 and 13. If the first and second sectors were the only sectors within the building, they could be considered contiguous sectors. In this example there are two

5   more sectors, which make the overall sectoring arrangement non-contiguous. A third sector S_3, which includes floors 5, 7, 8 and 9, is serviced by the car 28. A fourth sector S_4 is serviced by the car 30. The fourth sector includes floors 2, 3, 4 and 6. As can be appreciated from Figure 1, floors 5 and 6 are not contiguous with other floors within their respective sectors. Accordingly, the overall grouping of floors into

10 sectors is non-contiguous.

One example technique of arranging the sectors as shown in the illustration of Figure 1 includes initially arranging the floors into preliminary, contiguous sectors and then changing one floor from one sector with one floor from another sector. In the illustrated example, floors 5 and 6 were effectively swapped between the third and

15 fourth sectors to achieve the illustrated arrangement.

Swapping floors between contiguous sectors is one technique designed according to this invention. It is possible to swap floors as many as N times, where N is an integer that is less than the total number of floors serviced by the cars in the elevator system. Figure 2 illustrates an arrangement where N = 3. In the illustrated

20 example, the first through fourth sectors originally could be grouped to be contiguous followed by a swap of floors between the first and second sectors, the second and third sectors and the third and fourth sectors. Such an arrangement as illustrated in Figure 2 is the result.

Although the sectors are not contiguous, the average reversal floor for each car

25 is not significantly increased compared to an arrangement where all of the sectors are contiguous. Accordingly, the example of Figure 2 still presents a significant improvement of the handling capacity compared to systems where no sectoring is applied. To maximize the handling capacity using this technique, it is desirable to minimize the "upward movement" (i.e., during the swapping of floors) of the "upward

30 moving" floor. For example, it is better to swap floors 5 and 6 between the third and fourth sectors than it would be to swap floors 5 and 8 as the floor moving upward

from the fourth sector would have to "move" an additional two floors upward during the swap.

In one example, the interchange of floors between sectors does not include all possible two-floor interchanges between otherwise contiguous configurations. In this example, the non-contiguous configurations include N interchanges applied to a preliminary, contiguous configuration, where N is the smallest integer greater than or equal to half the average sector size over all sectors in a building where the size of the sector is the number of floors.

Symbolically, assume a building has N floors and m sectors, with sector sizes of f_1, f_2,..., f_m. Define $F=(f_1 + f + ... + f_m)/m$. According to this example, a nearly contiguous arrangement would be any sector grouping that is no more than the smallest integer greater than or equal to F/2 away from a contiguous sector grouping.

One example includes a building having twenty floors (i.e., N=20). There are four sectors (i.e., m=4). The number of floors f within the four sectors are as follows: $f_1 = 5$, $f_2 = 6$, $f_3 = 4$, $f_4 = 7$. Accordingly, F = (5+6+4+7)/ 4=5.5. F/2 = 2.75, therefore, the smallest integer greater than or equal to 2.75 is 3. In this example, any arrangement that is not more than three interchanges from a fully contiguous arrangement of sectors satisfies the example criteria. In this example, there are overlapping sectors. In instances where there are non-overlapping sectors, F=N/m.

Another technique designed according to this invention includes using top-weighted sectoring. This is shown, for example, in Figure 3. In this example there are four sectors, S_1, S_2, S_3 and S_4, with four floors per sector. This technique can be implemented by following the strategy where there are S sectors and F floors per sector. Grouping the top F -1 floors with the Sth floor establishes a sector. The next sector includes the next highest unassigned F -1 floors and the S -1th floor. This process is repeated until all floors are allocated into a sector.

In the example of Figure 3, there are four sectors (S=4) and four floors per sector (F=4). The first sector S_1 is assigned to the top three (i.e., 4-1) floors. The fourth floor (i.e., floor 5 in the illustration). The second sector S_2 includes the next available three top floors and the floor beneath the fourth floor (i.e., floor 4 in the illustration). Similarly, the third and fourth sectors are assigned in order.

Another technique designed according to this invention is referred to as modulous sectoring and one example implementation is referred to as K-modulous sectoring. This technique includes grouping floors into sectors based on an equivalence modulo K, where K is some positive integer greater than or equal to two.

5   Generally, the building is divided into K preliminary, contiguous sectors and then each of those sectors are divided into M non-contiguous subsectors, resulting in K*M non-contiguous sectors.

An example arrangement using K modulous sectoring where K=2 results in even-odd assignments for sectors. In one example, all even numbered floors would

10   be considered one sector and all odd numbered floors would be grouped into a second sector. For example, one car could be assigned to the even numbered floors from a fixed beginning floor to a selected ending floor for a sector. Another car could be assigned to the odd numbered floors between the same beginning and ending floors.

In the example of Figure 4, the building is originally divided into two

15   preliminary, contiguous sectors. Floors 2-9 are one preliminary sector and floors 10-17 are another preliminary sector. Each of the preliminary sectors are then subdivided into sectors. In the example of Figure 4, the two preliminary sectors are divided by two so that four sectors S_1-S_4 result. In the illustration of Figure 4, the car 22 is assigned to the first sector S_1, which includes floors 17, 15, 13 and 11. The car 30 is

20   assigned to the fourth sector S_4, which includes floors 8, 6, 4 and 2. In that example, K and M equal two.

Generally speaking, the K-modulous grouping technique assigns cars to cover floors that are evenly spaced from each other (i.e., every K^{th} floor between a selected starting floor and a selected ending floor). This technique can be described using the

25   following notation.

Assume an example where a building has C elevator cars and f floors. The floors are originally grouped into preliminary, contiguous sectors of contiguous floors where the Jth contiguous sector begins at floor (start)$_j$ and ends at floor (end)$_j$. Assume that t of the C cars will serve the jth preliminary, contiguous sector. Then, a

30   K-modulous sectoring dispatching grouping and car assignment entails the following:

t is greater than or equal to k;

the car C_i, where i equals 1, 2, ... k, has an assigned sub-channel consisting of those floors where i = floor number (mod k), restricted to being between floors (start)$_j$ and (end)$_j$; and

if t is greater than k, the cars numbered greater than k are assigned to handle the same floors in the sector if and only if i =j (mod k).

It should be noted that in an example where k=1, the result would provide contiguous sectors.

As a numerical example, assume there are twelve cars in a building and 40 floors (i.e., C=12 and f=40). Assume the building floors are grouped into four preliminary, contiguous sectors with the first sector including floors 1-10, the second sector including floors 11-28, the third sector including floors 29-34 and the fourth sector including floors 34-40. Let j=2, so that we consider the second sector (i.e., floors 11-28). This provides (start)$_2$=11 and (end)$_2$=28. Assume further that six of the twelve cars will service this particular preliminary sector (t=6).

In an example where K=3, car C_1 handles calls to and from floors 13, 16, 19, 22, 25 and 28 as each of these floor numbers have a remainder of 1 (the subscript of the car number) when divided by three (which is the value of K). Similarly, the car C_2 handles calls to and from floors 11, 14, 17, 20, 23 and 26. The car C_3 handles calls to and from floors 12, 15, 18, 21, 24 and 27. The floors assigned to each car establish non-contiguous sectors.

In this example, t is greater than k so that car C_4 handles the same floors as car C_1 since 4=1 (mod 3). Similarly, the car C_5 handles the same floors as car C_2 and car C_6 handles the same floors as C_3.

In one example, the cars are assigned or labeled in a dynamic fashion such that, for example, the car 24 in Figure 4 is not always car C_i. Each sector for a car is effectively based upon equally spaced floors within a preliminary, contiguous sector.

The preceding description is exemplary rather than limiting in nature. Variations and modifications to the disclosed examples may become apparent to those skilled in the art that do not necessarily depart from the essence of this invention. The scope of legal protection given to this invention can only be determined by studying the following claims.